# Accelerator Research and Development in support of APS user operations

- Beam Stabilization Plans

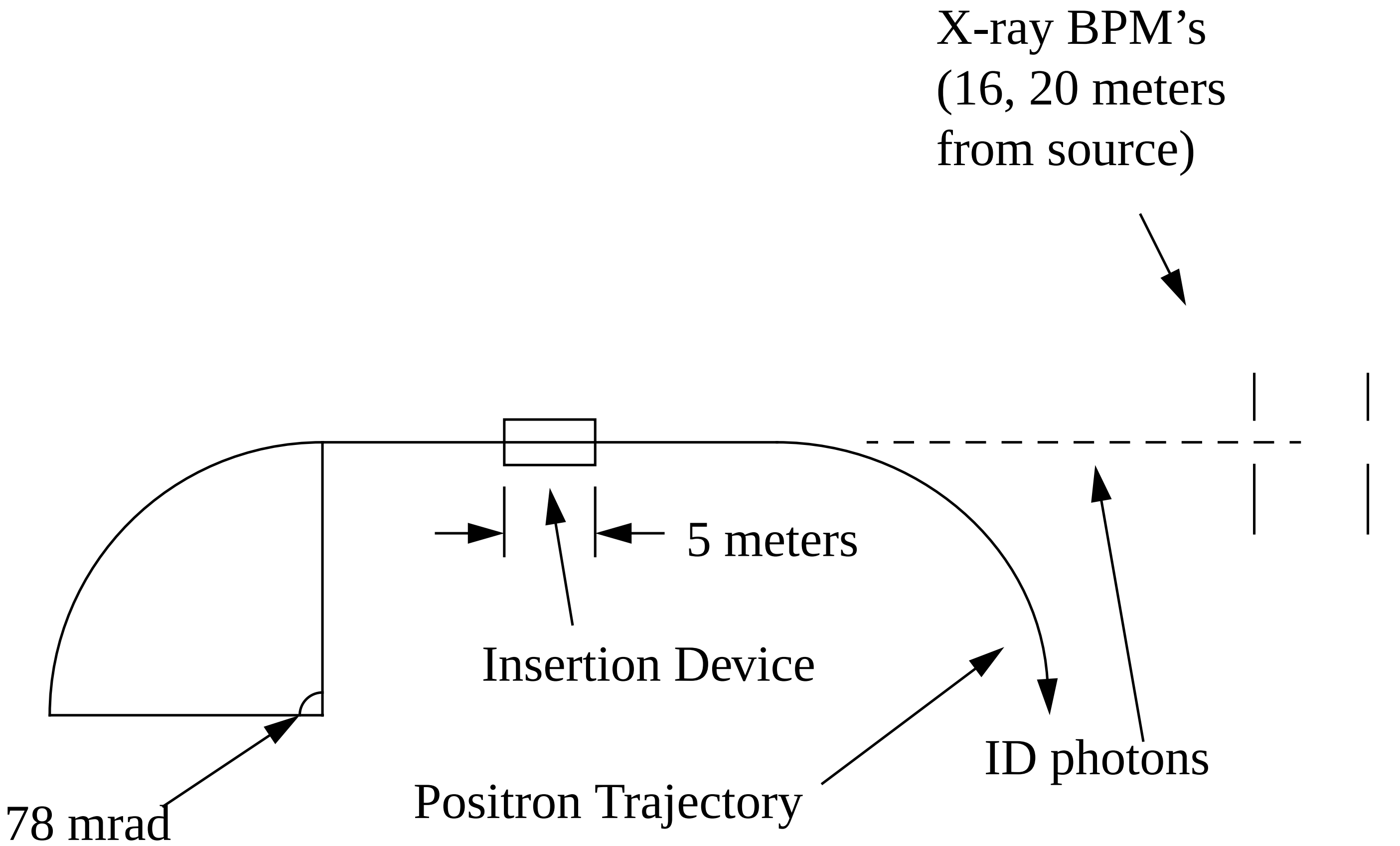
  A method for reducing X-ray background signals from insertion device X-ray beam position monitors
- Top-up experience and plans
- Horizontal emittance reduction
- Bunch length studies
- Doubled-up undulators

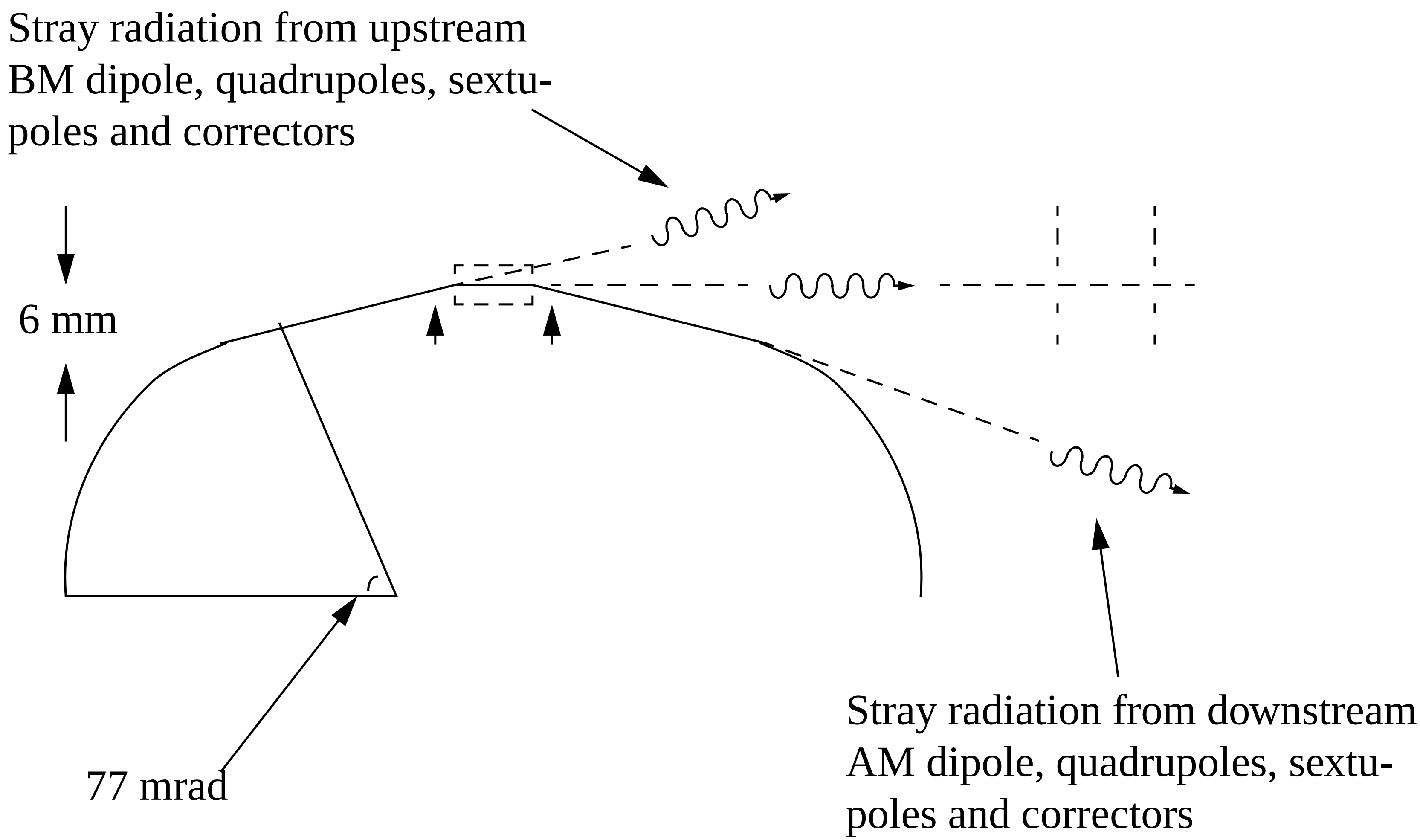
# A Method for Reducing X-ray Background Signals from Insertion Device X-ray bpm's

**G. Decker**

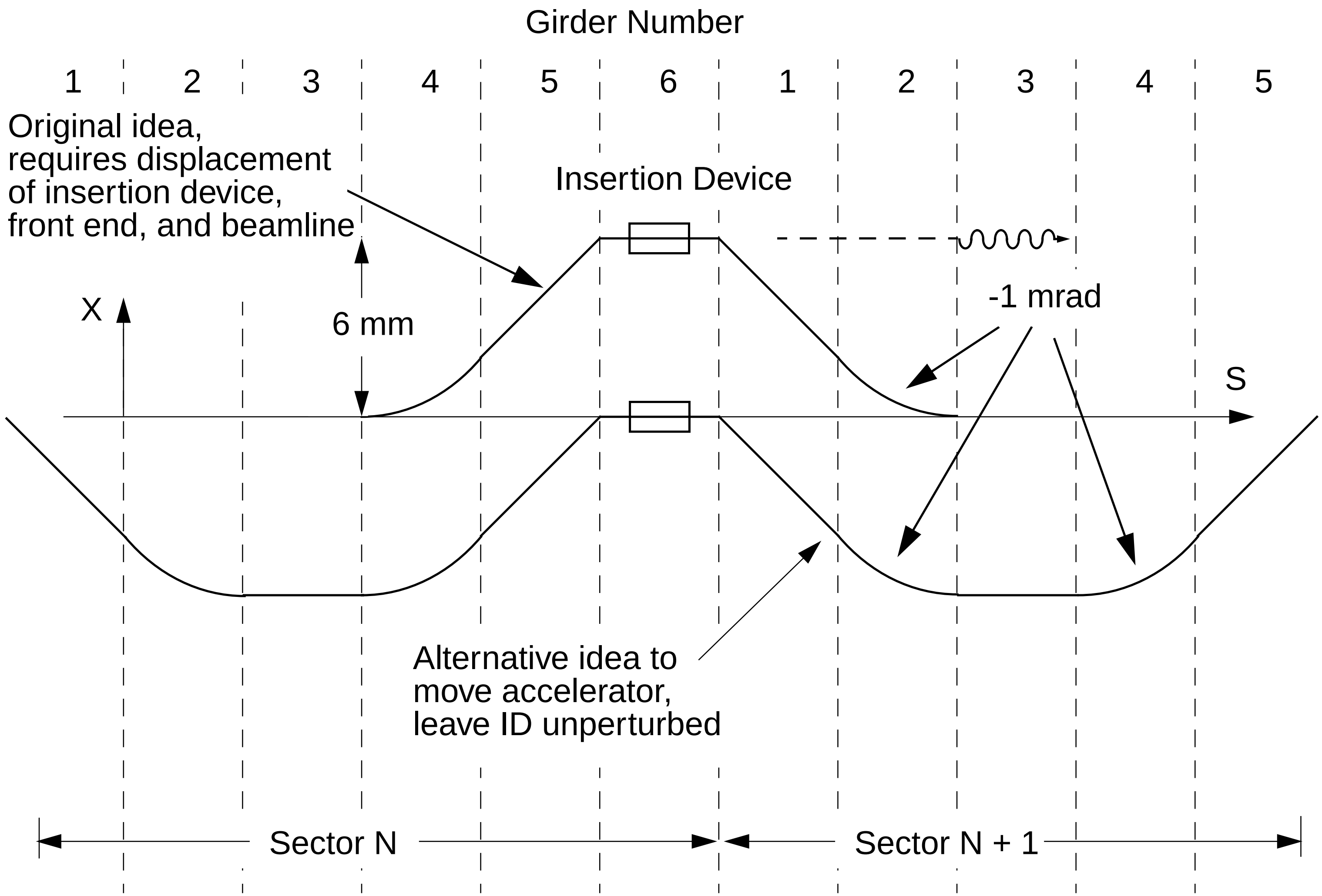
- RF bpm's by design are most effective at reducing global rms orbit errors, while X-ray bpm's were designed specifically for local source point control.
- Lever arm for X-ray bpm's derive from 16 to 20 meter source-detector distance,while rf bpm separation at ID's is only 5 meters.
- ID X-bpm's have superior mechanical and thermal stability properties, however we are unable to take advantage of this as a result of variable stray radiation backgrounds. No one in the world has a good solution for this problem. Closed-loop orbit control on undulator beamlines is rarely attempted - ESRF ignores their ID X-ray bpm's.
- The stray radiation emanates from steering correctors(12), dipole magnets (2), quadrupole magnets (6), and sextupole magnets (4), and cannot be compensated for at even the few micron level.

# Concept for Elimination of X-bpm Background Signals




Stray radiation from upstream BM dipole, quadrupoles, sextu-poles and correctors
6 mm
77 mrad
Stray radiation from downstream AM dipole, quadrupoles, sextu-poles and correctors

# Insertion Device vs. Accelerator Displacements

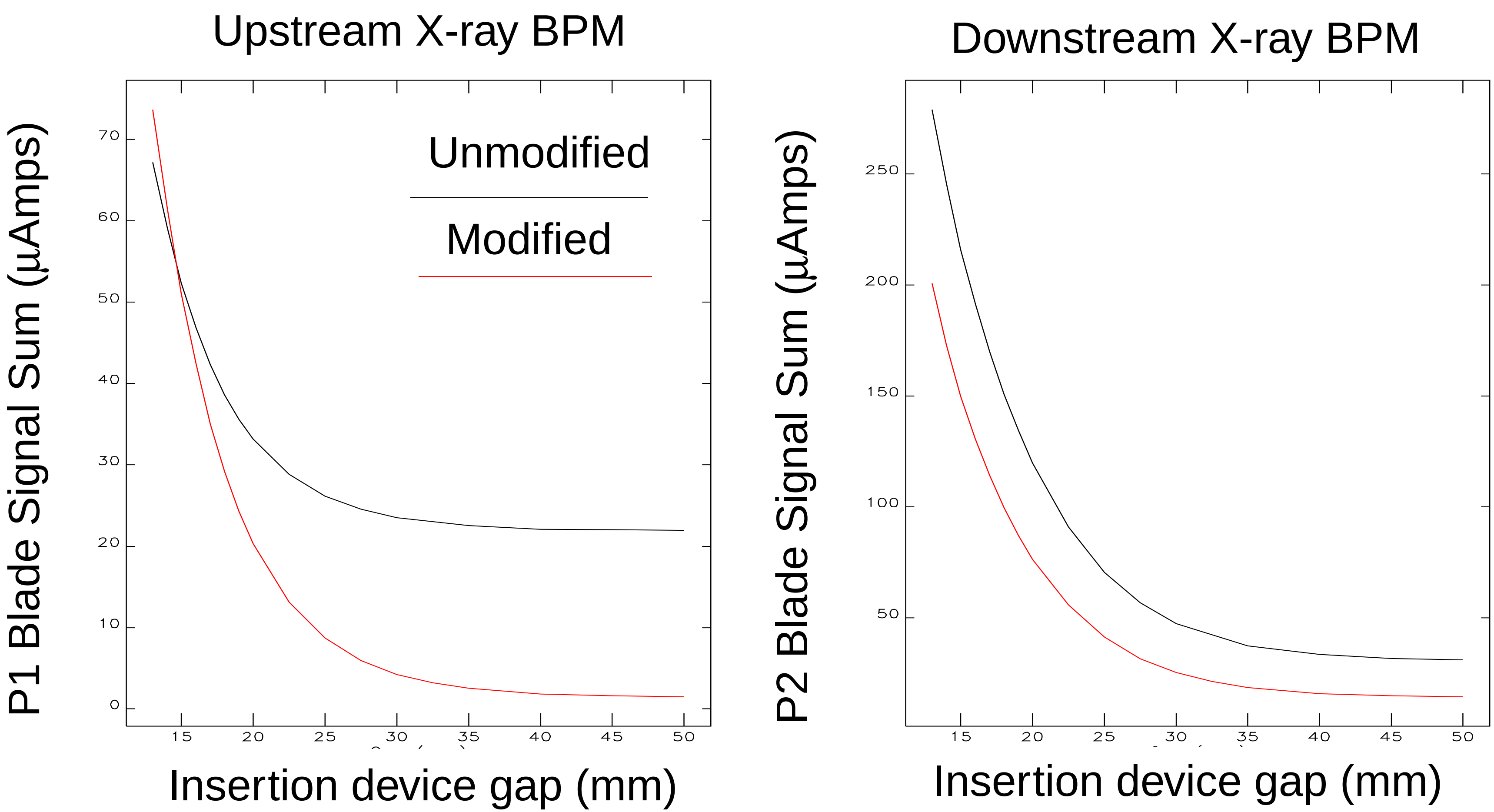



Note - angle shown is dipole magnet strength _change_ ,
i.e. -1 mrad means 78 mrad total decreased to 77 mrad.

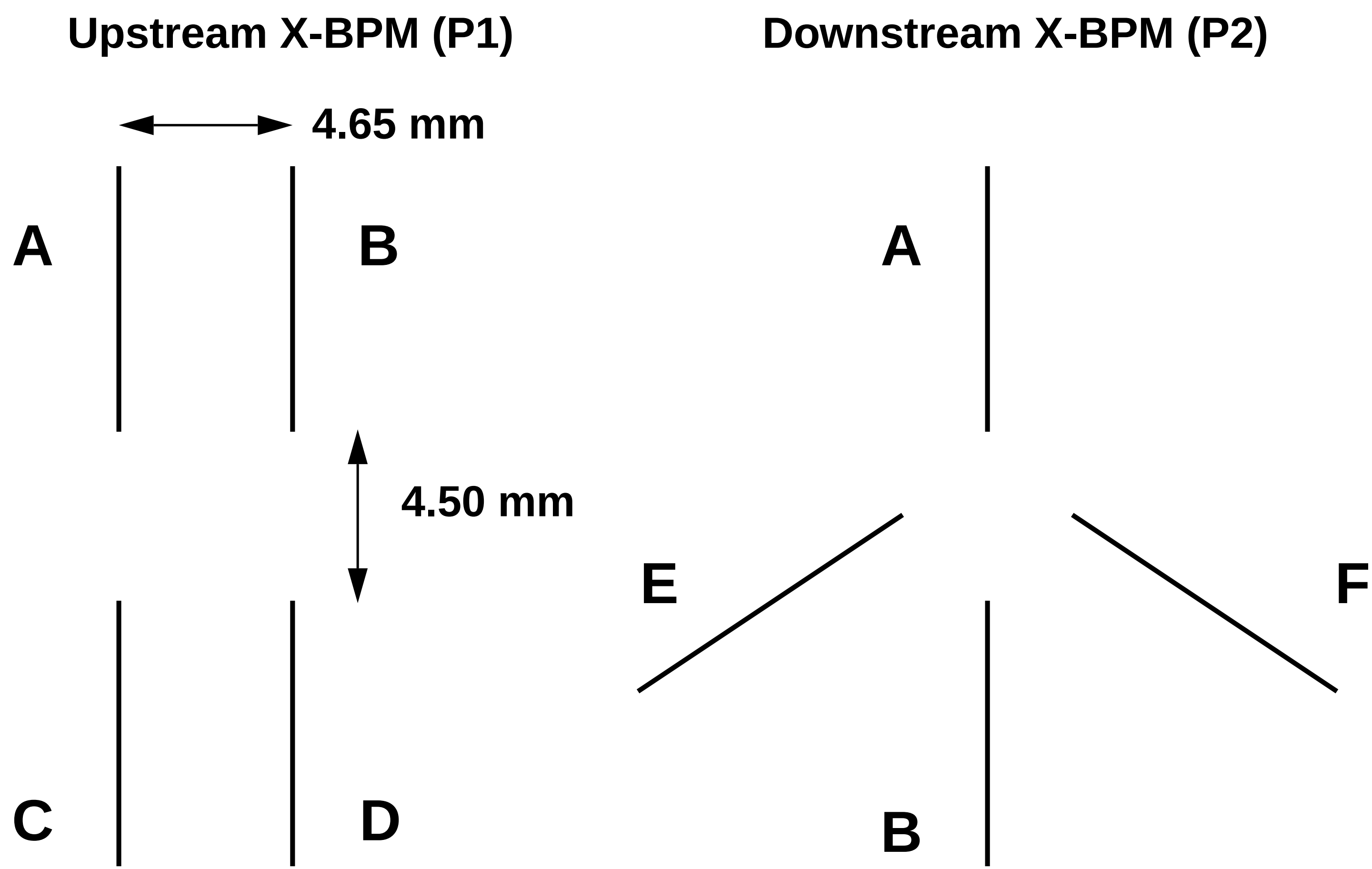
# Implementation Issues

- Bending magnet beamlines impacted.
  - 0.3 mrad nominal outboard rotation, intersecting original beamline at ratchet wall
- Front end components require minor realignment.
- Formed bellows constrain adjacent girder motions to angles only.
- Dipole magnet trim windings must be powered.
  - Trim supplies have been successfully operated since 1/99 with no effect on beam jitter.
- New mis-steering interlock trip limits required.
- Sector 34 /35 inboard accelerator displacement completed 12/98.
- Girder movement executed under vacuum, requiring 24 crew-hours / sector
- Sector 33 displacement completed 4/00, studies begin next week.

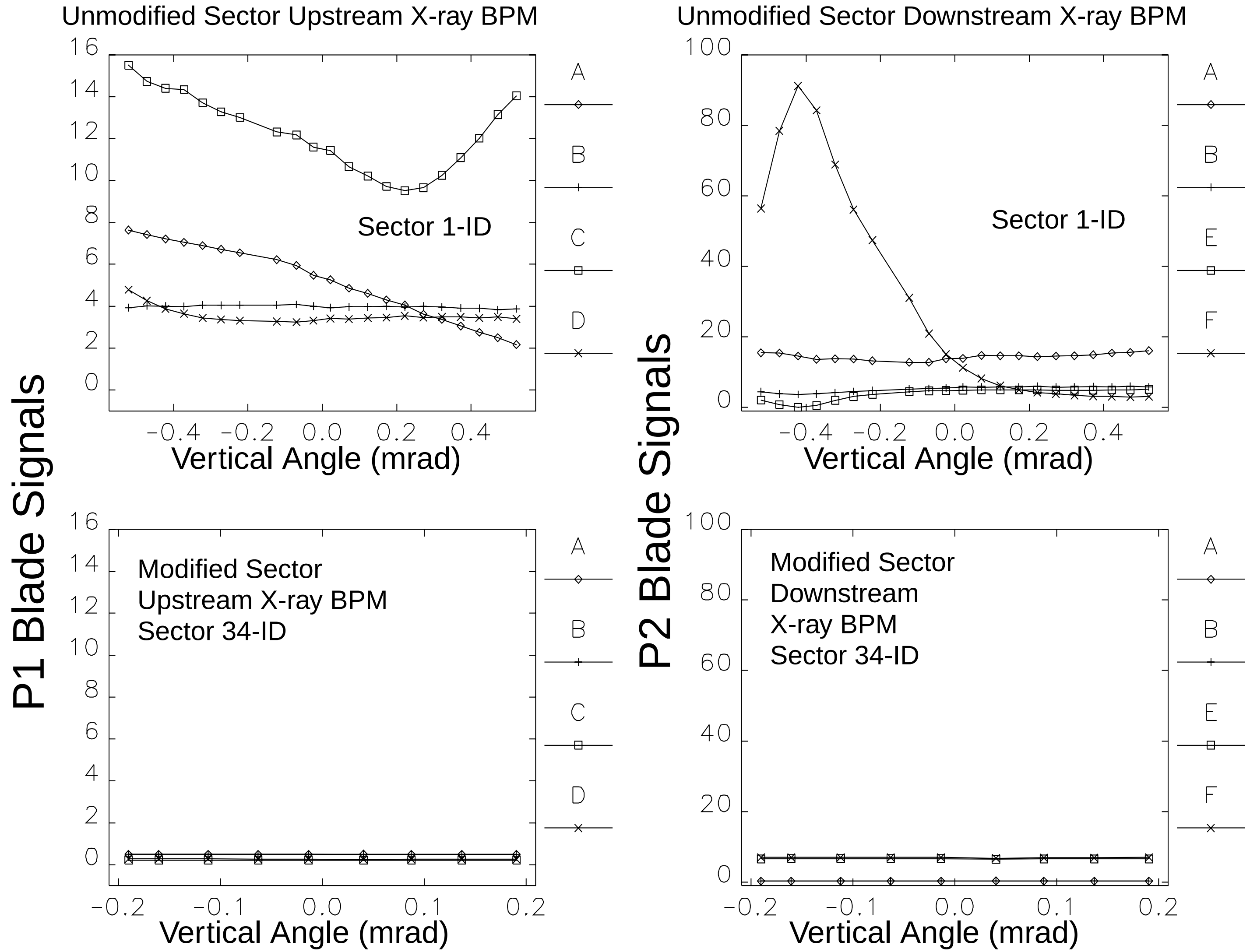
# Variation of X-ray bpm blade signal sum with ID gap



## APS Insertion Device X-ray BPM Blade Geometry



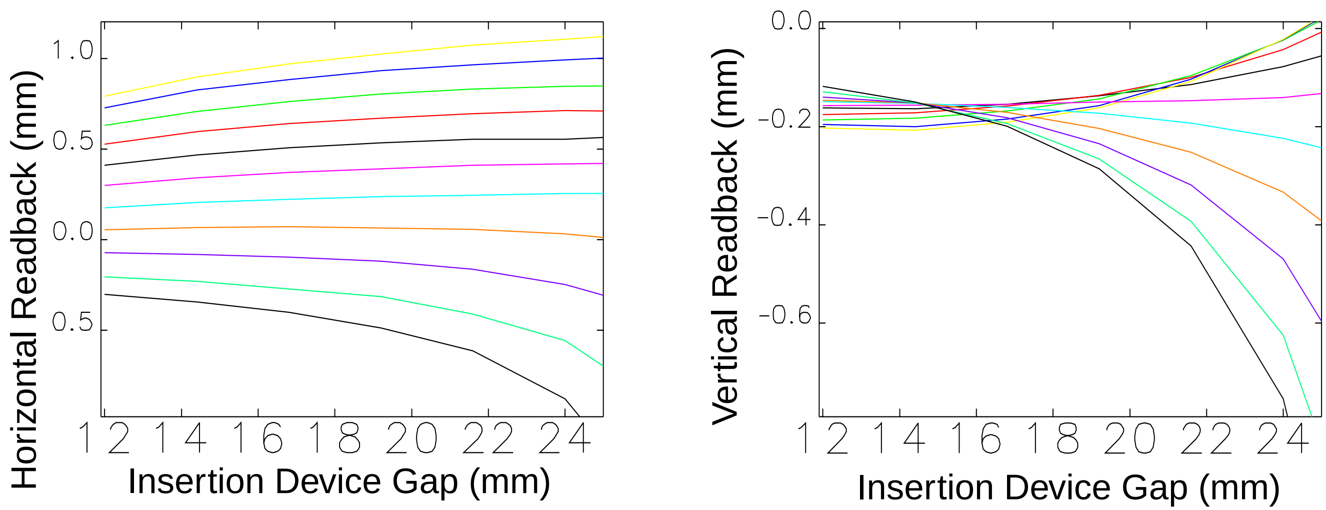
# Effect of local steering through AM dipole on ID X-bpm blade signals



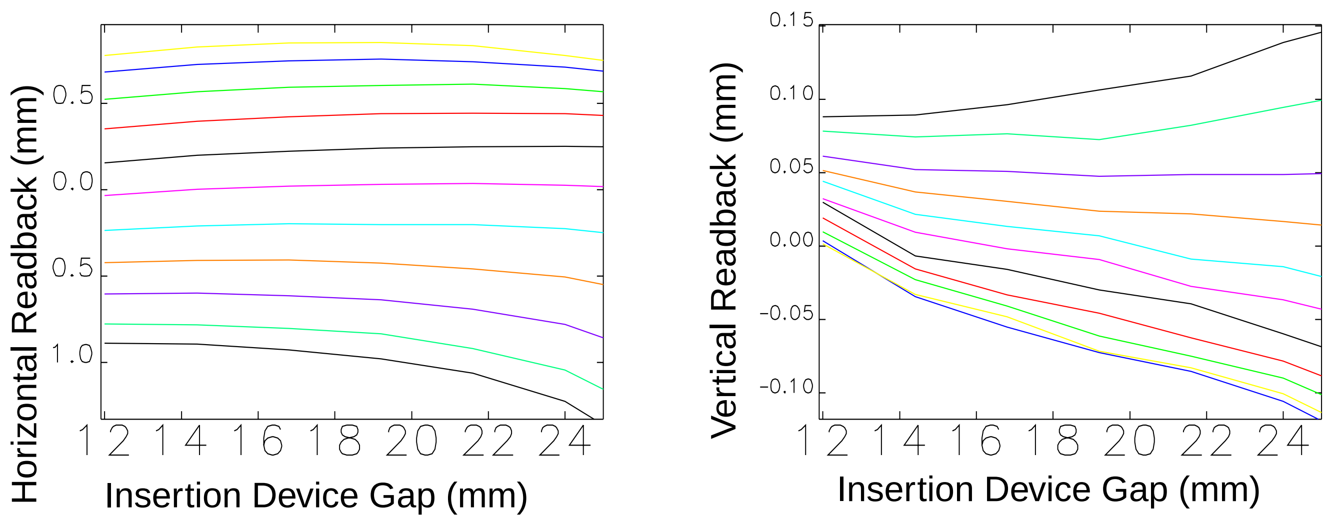

Argonne National Laboratory
Advanced Photon Source
AOD Diagnostics

User Meeting
Glenn Decker
May 3, 2000

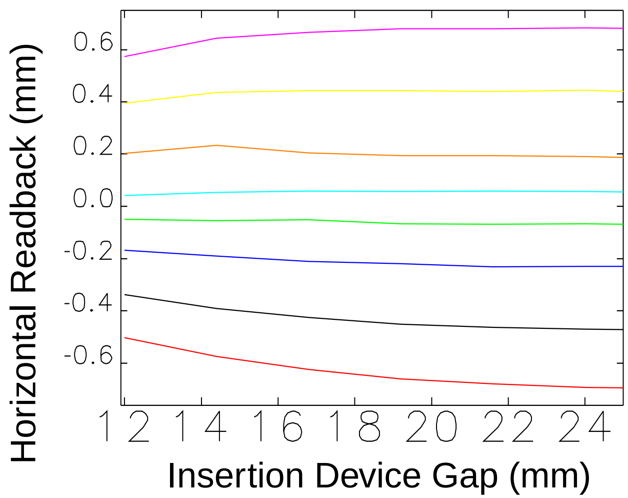
## Unmodified Sector (1-ID) Upstream X-ray

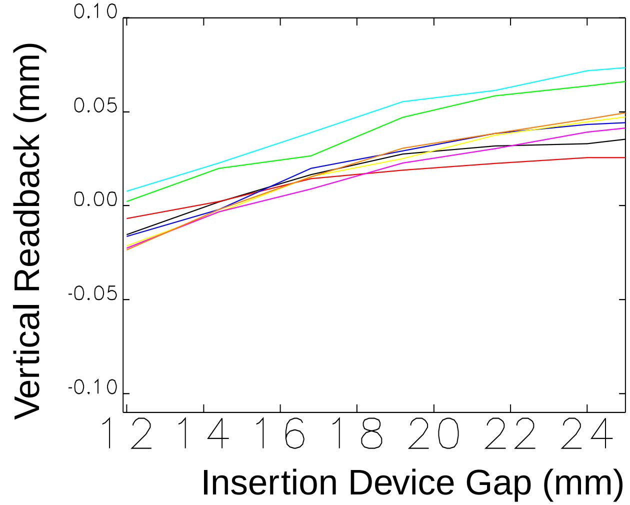



## Unmodified Sector (1-ID) Downstream X-ray

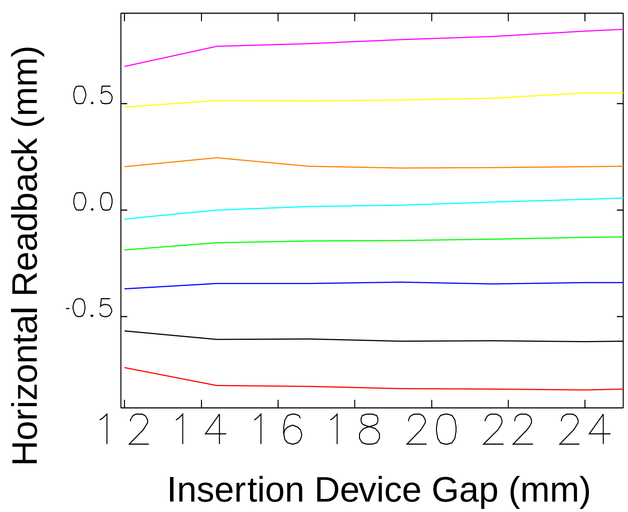


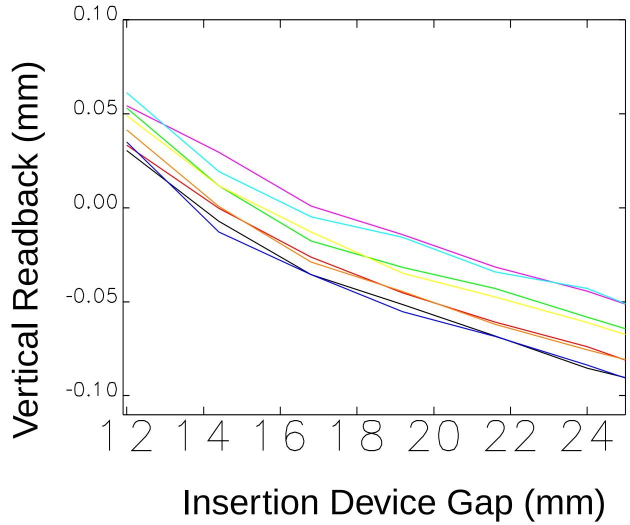
## Modified Sector (34-ID) Upstream X-ray BPM




## Modified Sector (34-ID) Downstream X-ray BPM

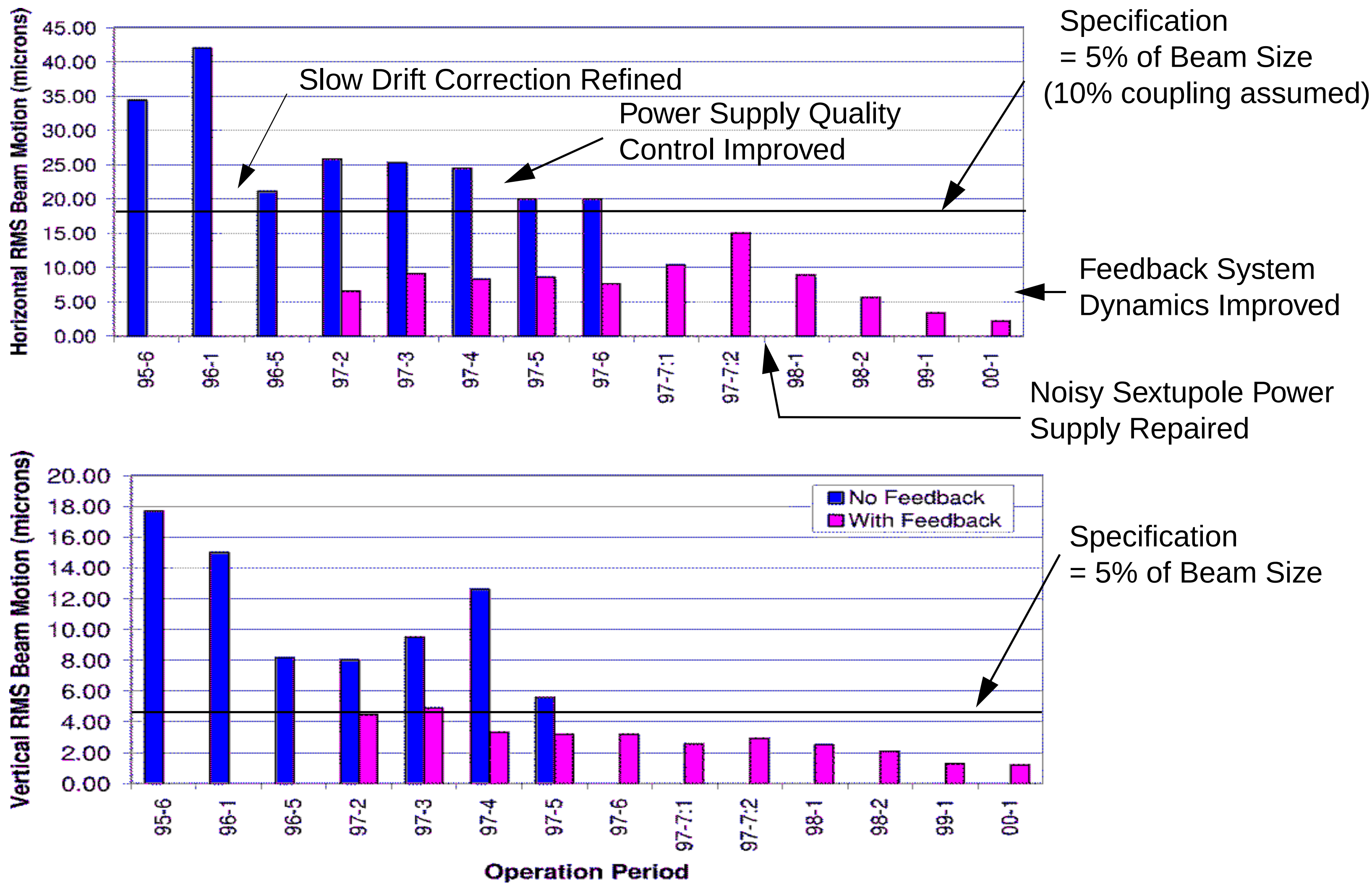


# Expected Beam Stability Improvement

- Ultimate performance dictated by X-bpm electronics noise floor and implementation. Ground motion is at the level of a few tens of nanometers, in a bandwidth from 2 to 50 Hz.
- A modest upgrade should allow a factor of greater than ten improvement in DC pointing stability over present performance, entering the realm of true sub-micron beam stabilization.
- Studies of the application of horizontal corrector radiation as a possible gap-independent position diagnostic are continuing.

# APS Horizontal and Vertical
# Beam Position Stability History (0.016 Hz - 30 Hz)

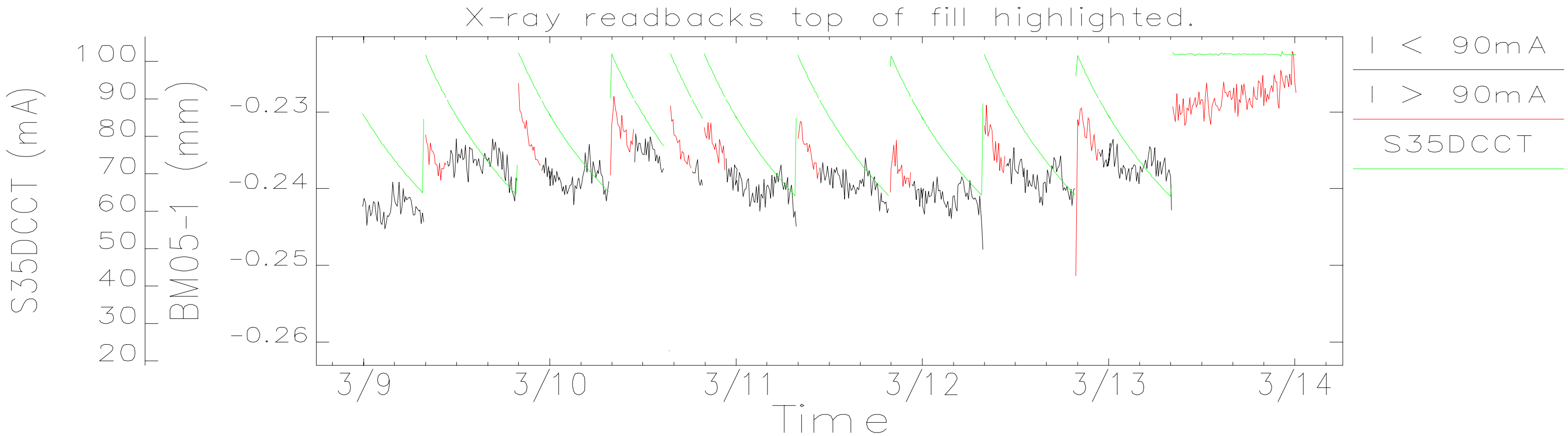


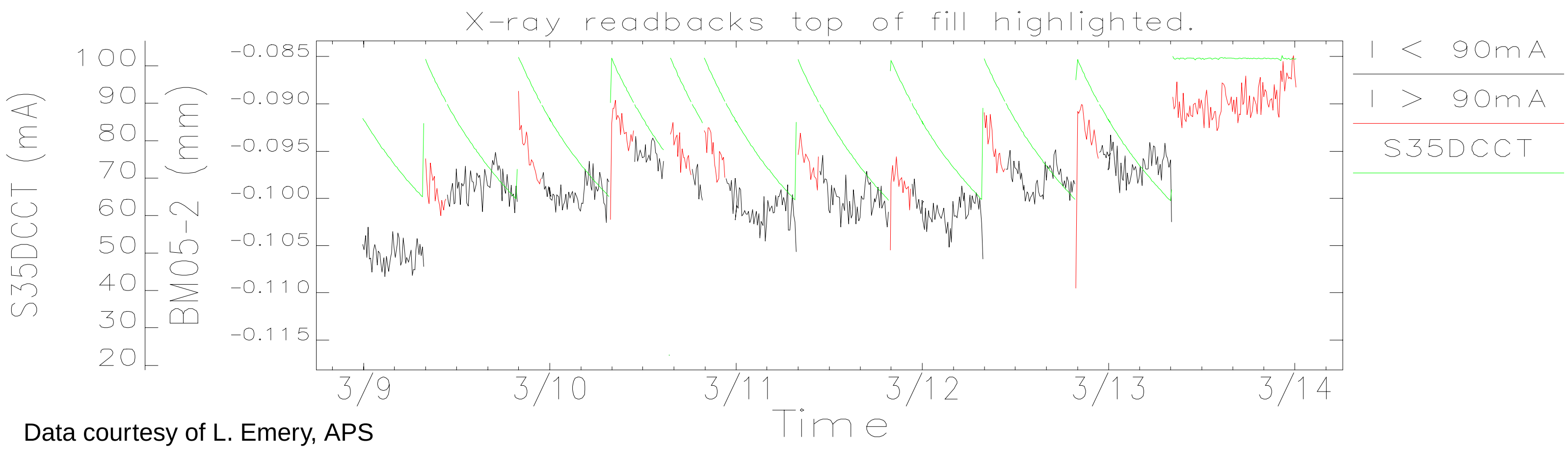
# Top-Up Experience and Plans

- Top-up = Quasi-continuous injection with shutters open
  - Every two minutes nominal
- Advantages
  - Improved stability of front end and beamline optical components
  - Improved mechanical stability of accelerator components (e.g. absorbers)
  - Reduction of systematic intensity dependency of beam position monitors
  - Allows special operating modes with normally short lifetime, i.e. high peak current or low coupling
- Disadvantages
  - Beam disturbance from injection process
  - Somewhat higher radiation dose impinging on insertion devices
  - Additional safety interlocks / analysis required.

# Top-up Operating Modes (cont'd)

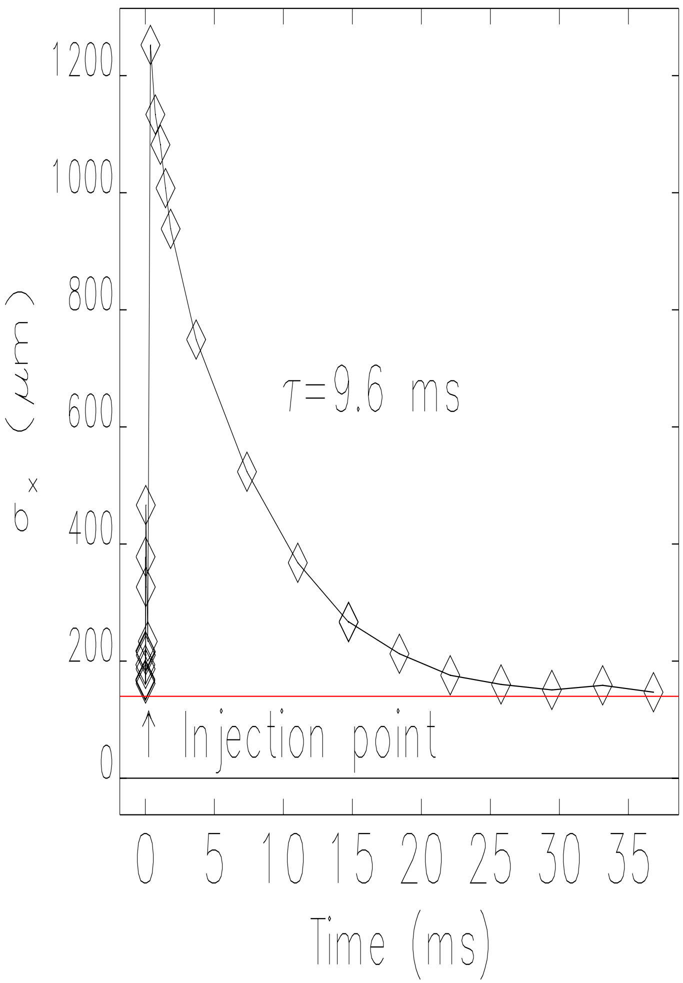
Example of X-ray BPM readback during several days with top of fill (I > 90 mA) highlighted.



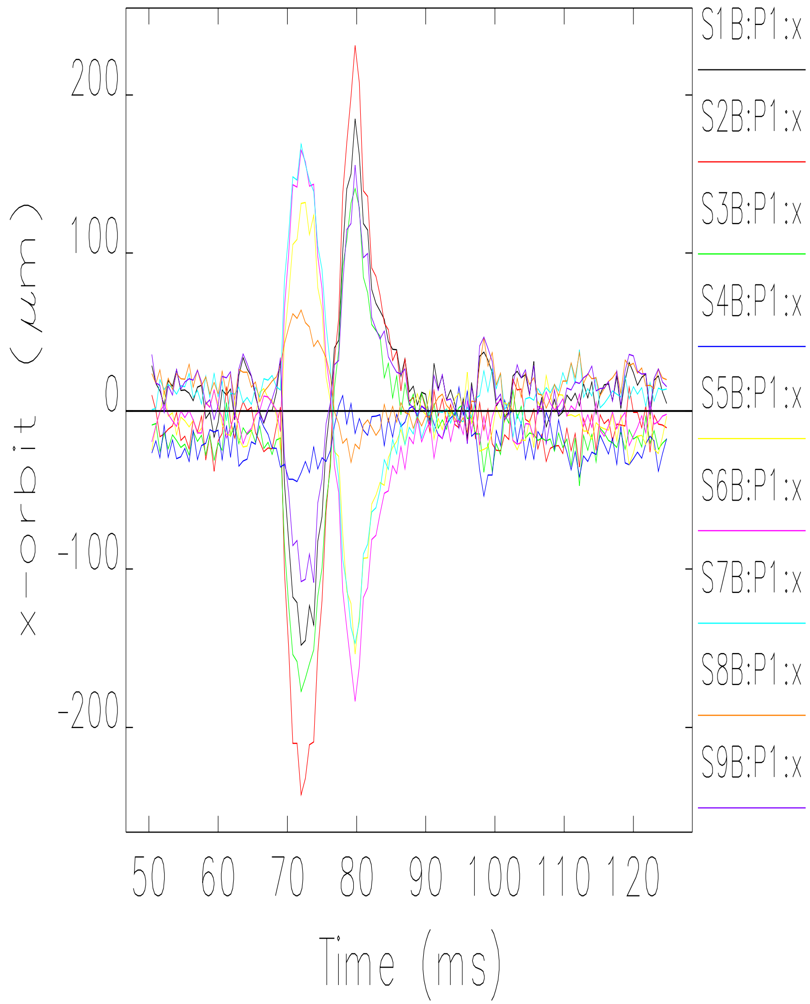

Data courtesy of L. Emery, APS

## Beam Size Injection Transient




Data courtesy of L. Emery, APS

## Orbit transient from Pulsed Septum

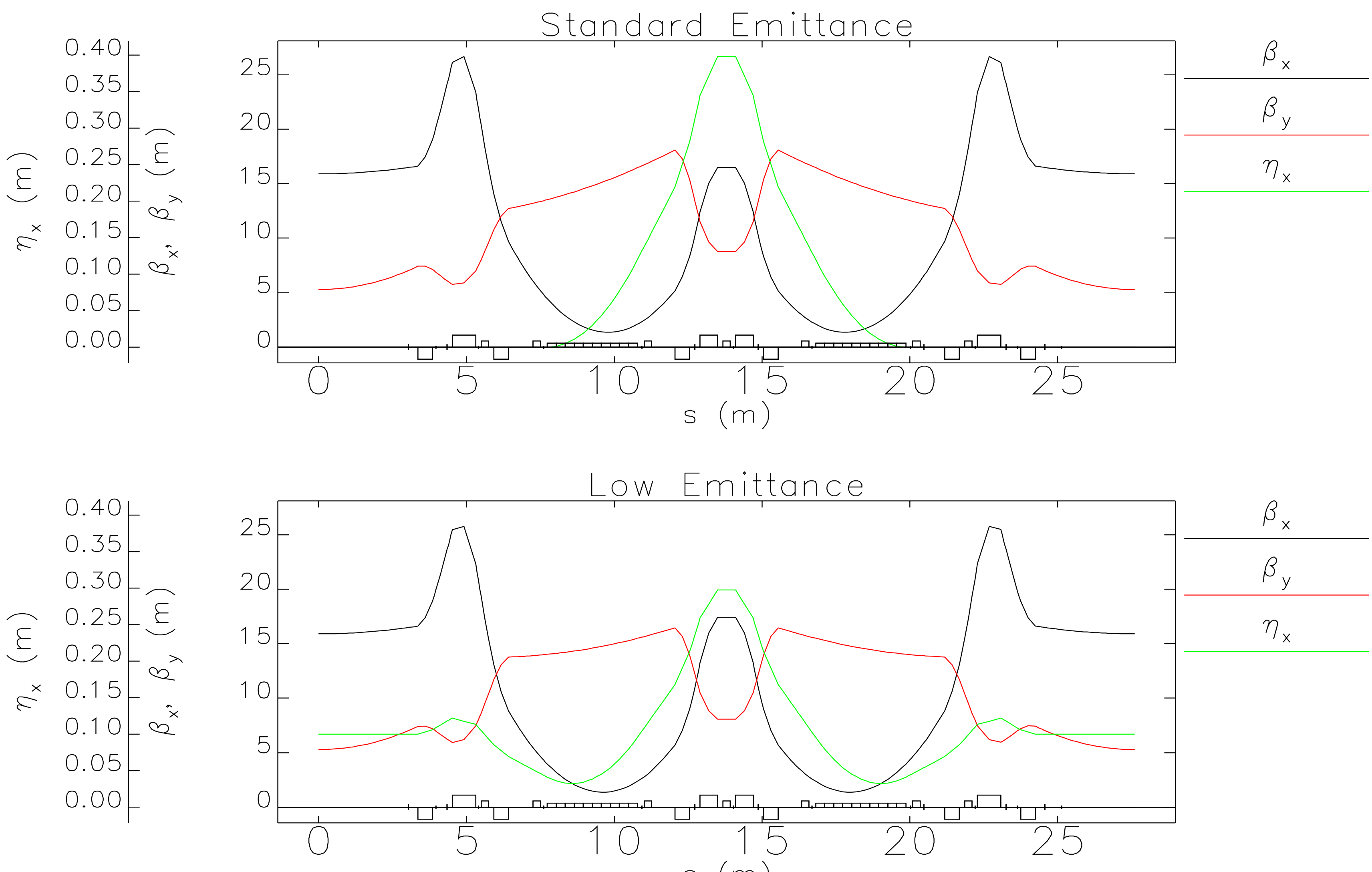


# Top-up Summary

- Successful operation during two separate 24-hour periods
  - Good injector availability
  - Improved orbit stability
- Gate signal distributed to users to deal with injection transients
  - Work continues to reduce beam perturbations
- Present regulation $\Delta I / I = 10^{-3}$
  - Investigations of regulation at $\Delta I / I = 10^{-4}$ ongoing.
- Planned for user operation June 27 - July 3

# Low Horizontal Emittance Studies

- Relatively simple lattice modification yields factor of two reduction
- Advantages
  - Smaller horizontal beam size / angular divergence
  - Higher X-ray brightness
- Disadvantages
  - Reduced lifetime (for same coupling)
  - Lifetime Touschek-limited
  - Small orbit perturbation
- Note - Emittance is reduced approx. 13% by closing all ID Gaps
- Further work required to understand this mode
  - 3.5 nm-rad achieved (Nominal is 8.2 nm-rad)

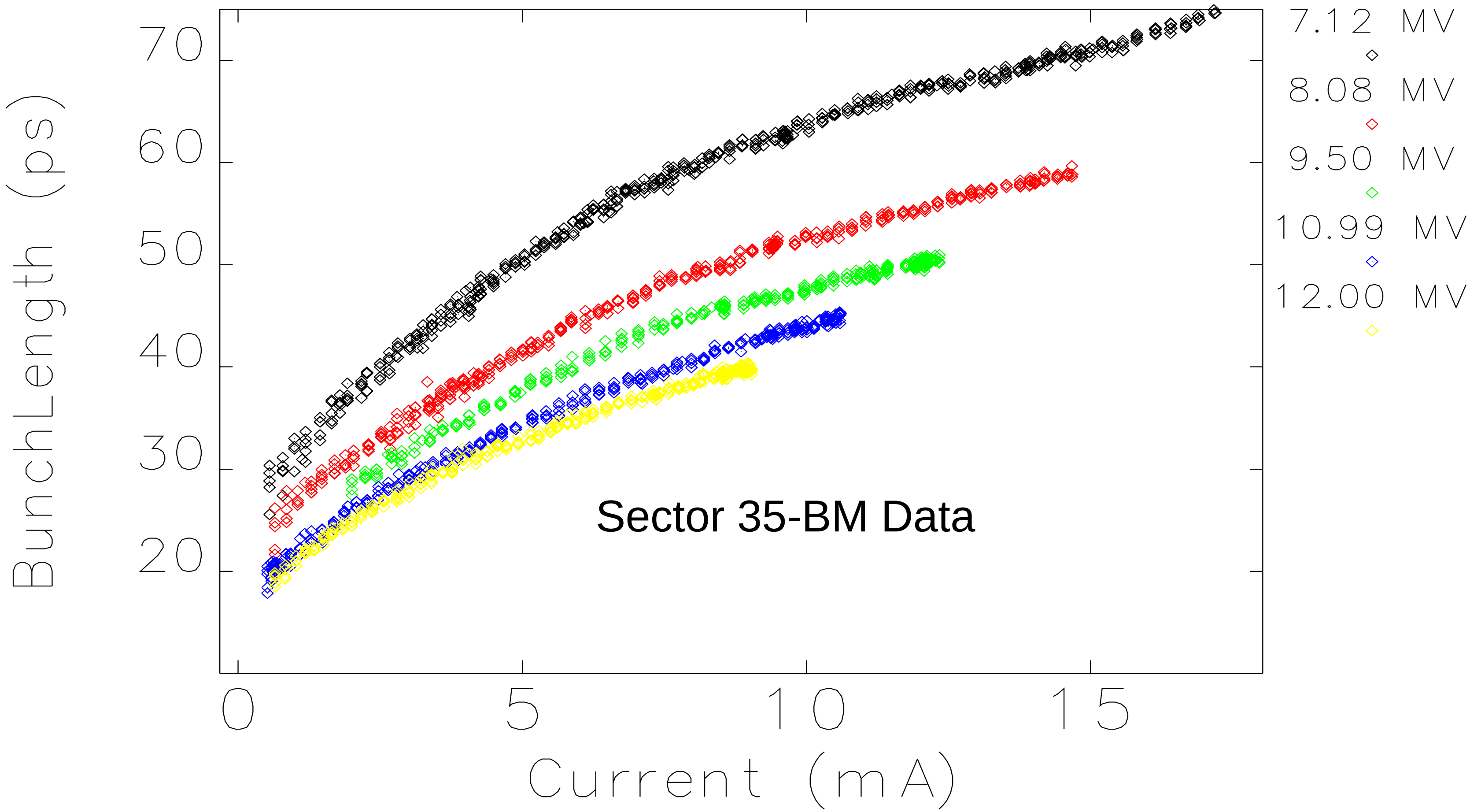



Graphics courtesy of L. Emery

# Bunch Length / High Peak Current Studies

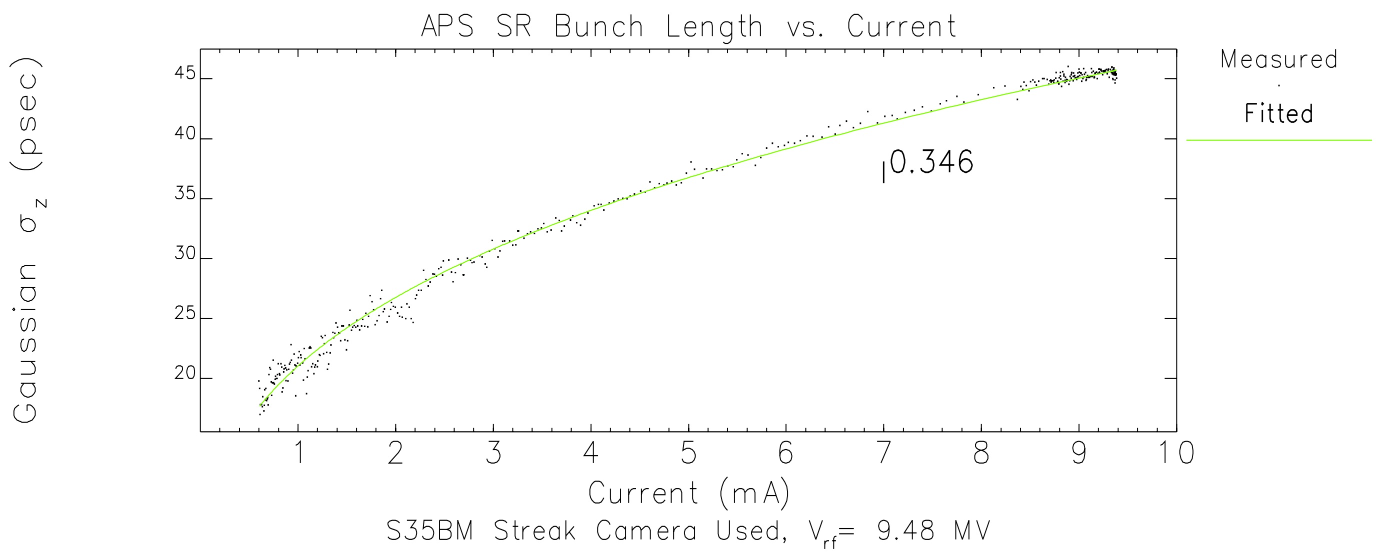
- Record single bunch current 19 mA
  - Typical 12 mA limit
  - Significant dependence of single bunch limit on RF voltage
  - Bunch lifetime poor with high peak current
  - Severe bunch lengthening (factor of 3 compared to low current value)
- Bunch length varies approximately as $I^{1/3}$.
- Energy spread data shows onset of single bunch instability at 7 mA
  - 10% effect on energy spread only.

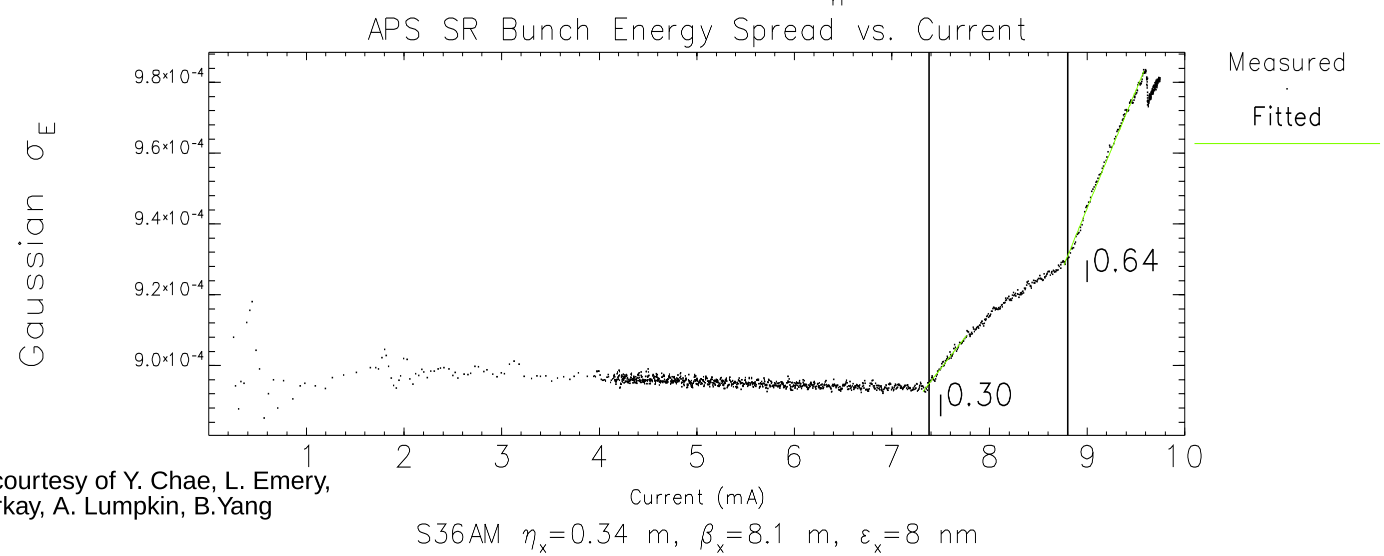
# Variation of Bunch Length with RF Cavity Voltage




Data courtesy of L. Emery, A. Lumpkin, B. Yang

# Bunch Length and Energy Spread vs. Single Bunch Current



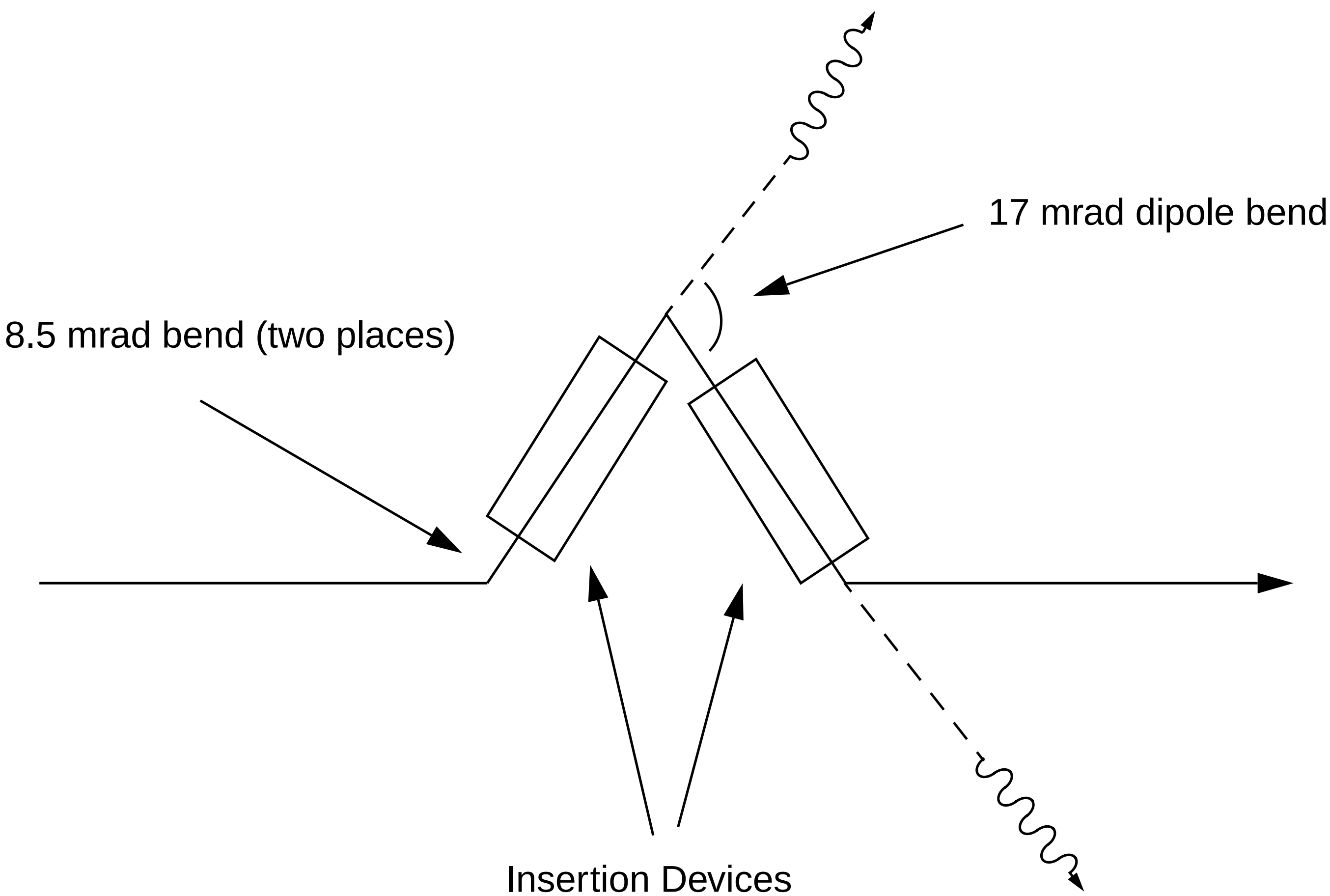




Data courtesy of Y. Chae, L. Emery,
K. Harkay, A. Lumpkin, B.Yang

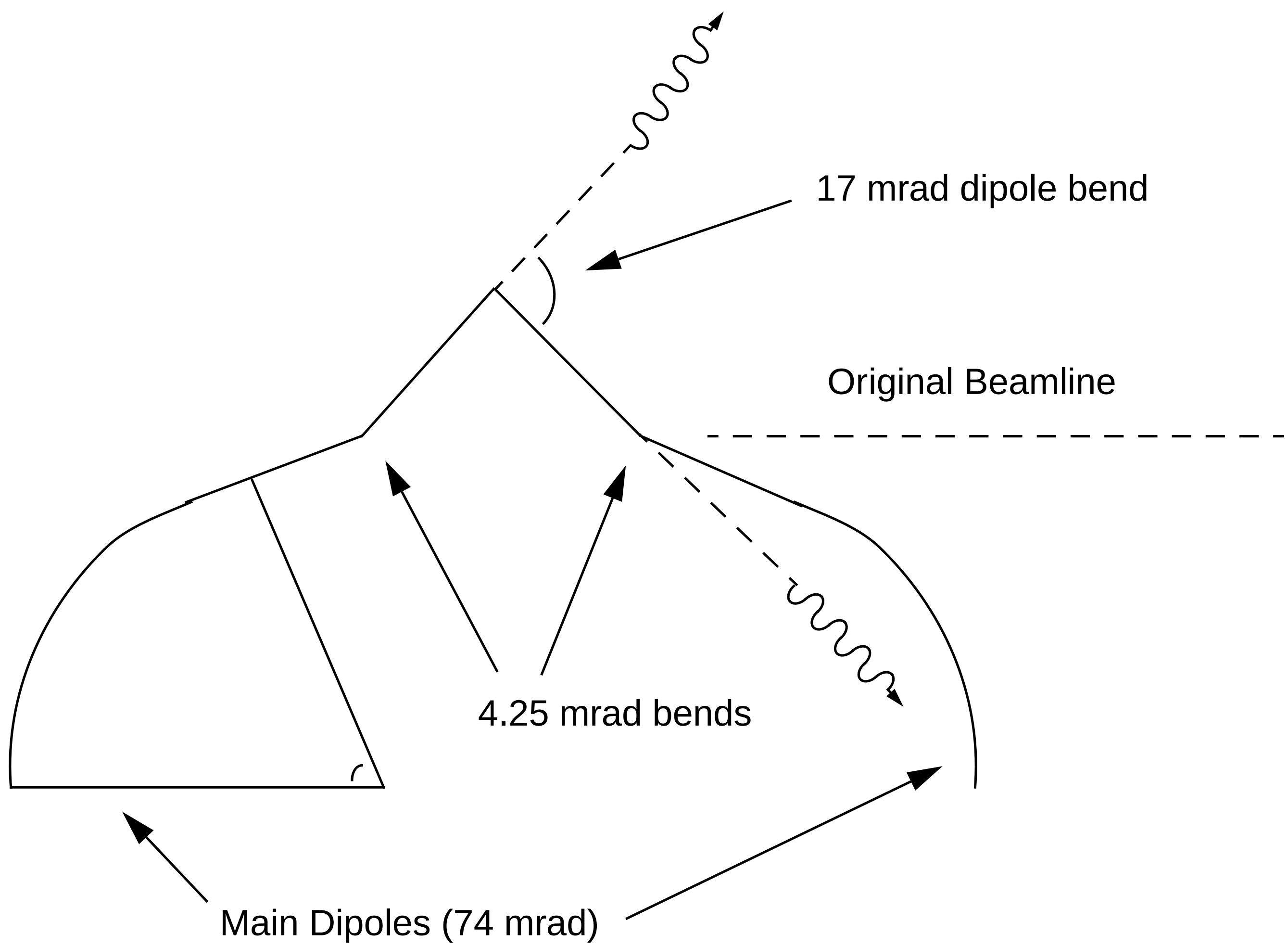
# Doubled-up Undulators

- Recent experience at 4-ID demonstrated 2 undulators / straight section
- However
  - Angular separation only 270 microradians
  - Pick-off mirror required - only good for soft x-rays
  - Larger angle required for e.g. two undulator A's
- Design study ongoing for 2 ID's with 1 degree (17 mrad) separation
  - This is a factor of 60 more angular separation than 4-ID
  - New front end design necessary
  - Accelerator vacuum chamber design impacted
  - Accelerator lattice parameters require adjustment - e.g. 8 mm orbit circumference change
- Much work remains - detailed planning continues

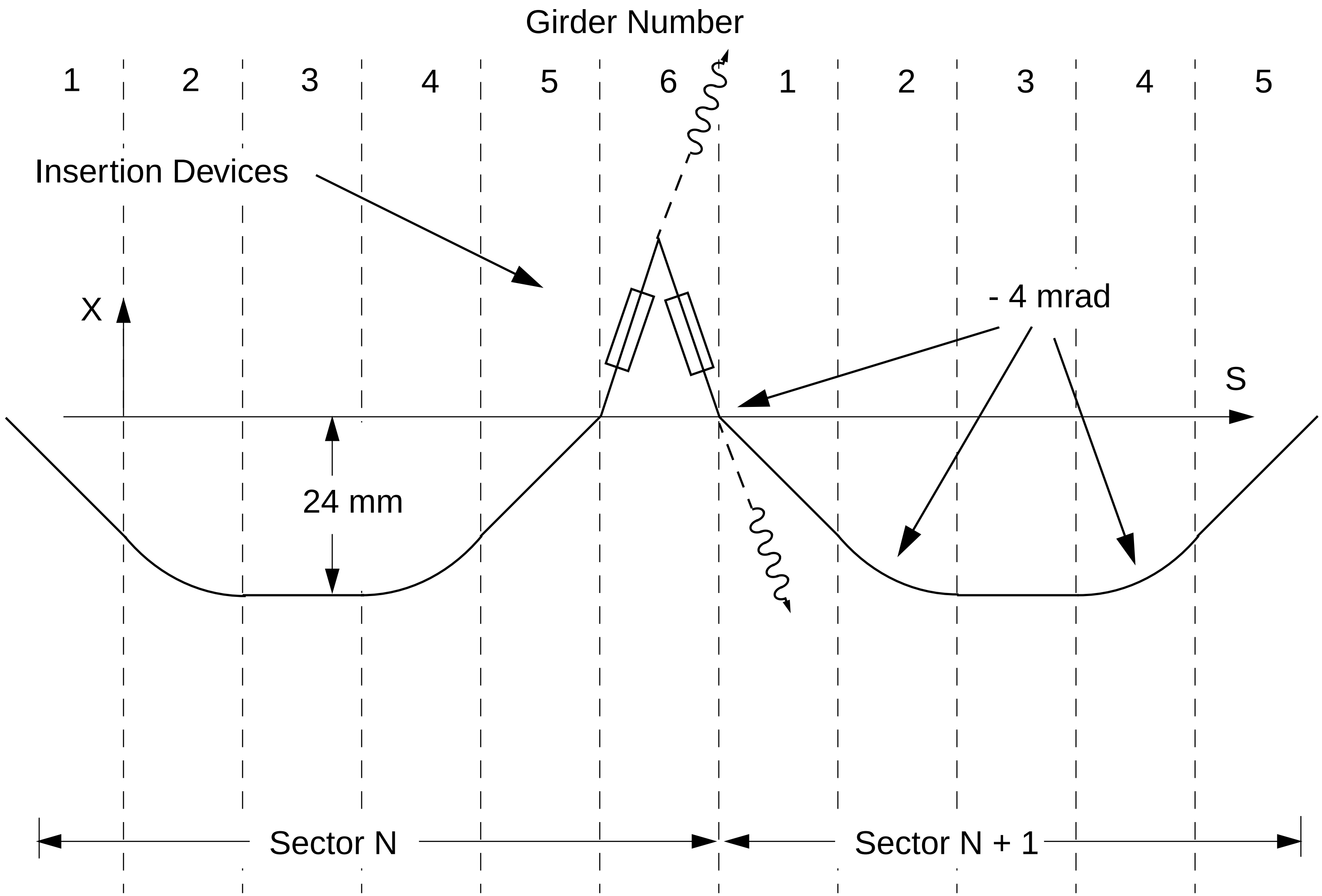
# Doubled-up Undulators Original Concept



# Modified Concept to Allow for Accelerator Apertures



# Girder Displacements for Doubled-up Undulators




Note - angle shown is dipole magnet strength _change_ ,
i.e. - 4 mrad means 78 mrad total decreased to 74 mrad.